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ScienceDirect

Solar Energy 127 (2016) 175–183

SOLAR ENERGY

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Identification of photovoltaic cell single diode discrete model parameters based on datasheet values

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Received 26 August 2015; received in revised form 13 January 2016; accepted 18 January 2016

Communicated by: Associate Editor Hari M. Upadhyaya

Abstract

In this paper, photovoltaic cell single diode detailed model is developed and simulated. Entire system parameters in the model are taken into account. To determine the model parameters based on datasheet values and analyze the model, MATLAB system function (S-function) feature is preferred. S-function is used to obtain the photovoltaic cell discrete and applicable model in real system to be able to use in an embedded system. Necessary mathematical equations belong to the photovoltaic cell model are converted to discrete form and are written in S-function with C codes. Also, the simulation of the photovoltaic cell model is realized by using MATLAB S-function feature. To analyze and verify the validity of the presented model, *I–V* and *P–V* characteristic curves obtained from S-function are compared with datasheet characteristic curves of two commercial solar panels which are Kyocera KC200GT and Siemens SP75. The proposed model can be applied to any brand of photovoltaic panel by setting the parameters properly using datasheet values.

Keywords: Equivalent circuit; Parameter determination; Single diode model; Photovoltaic cell; S-function

1. Introduction

Photovoltaic systems are one of the noteworthy renewable sources because of reliability, less operation and maintenance costs with no moving parts, no pollutant emission, and limitless energy source. Photovoltaic system contains photovoltaic device, power electronic converters, and maximum power point tracking control. Elementary part of the photovoltaic (PV) device is photovoltaic cell and it converts exposed sunlight to electricity. Cells can be connected to suitable loads directly or they can connect to power electronic systems to change their output voltage value and form (Villalva et al., 2009).

Cells can be grouped as panels or arrays. Panels are generally composed of series cells in order to obtain large output voltages. Panels with large output currents are achieved by increasing the surface area of the cells or by connecting cells in parallel. A PV array can be consisting of a panel or panels which are connected in series or parallel to obtain large PV systems (Villalva et al., 2009; Mohammed, 2011).

In the power electronic converter system design, modeling of the system parts plays an important role. In order to study with PV systems, first need is the circuit based model of the PV cell to be able to connect the PV panel to converters. Many researches have been done to obtain the model of the PV cell. Most of these models have nonlinear equations. There are some approximations in the literature. In the PV cell model, series resistance value is very small and shunt resistance value is very large and they may be

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http://dx.doi.org/10.1016/j.solener.2016.01.024
0038-092X/

Nomenclature

q	electron charge ($1.60217646 \cdot 10^{-19}$ °C)
k	Boltzman constant ($1.3806503 \cdot 10^{-23}$ J/K)
G_n	nominal irradiation (1000 W/m^2)
G	solar irradiation on the device surface (W/m^2)
T_r	reference temperature of the photovoltaic cell (K)
T	surface temperature of the photovoltaic cell
$P_{max,e}$	maximum power (W)
$P_{max,m}$	calculated maximum power (W)
V_{mp}	maximum power voltage (V)
I_{mp}	maximum power current (A)
V_{oc}	open circuit voltage (V)
I_{sc}	short circuit current (A)
K_v	temperature coefficient of V_{oc} (V/°C)
K_I	temperature coefficient of I_{sc} (A/°C)
N_s	number of cells connected in series
N_p	number of cells connected in parallel
E_{gap}	energy of the band gap (eV)
A	ideality factor
R_s	series resistance (Ω)
R_{sh}	parallel resistance (Ω)
I_{ph}	photocurrent source (A)
I_{rr}	reverse saturation current at a ref. temperature and solar irradiation (A)
I_{sat}	module reverse saturation current (A)
V_{out}	output voltage (V)
I_{out}	output current (A)

neglected to simplify the system. Some researchers eliminate shunt resistance to simplify the system (Pandiarajan and Muthu, 2011; Tsai et al., 2008; Dang et al., 2012) or they set up the model with different series and shunt resistances and check their effect on the system (Rodrigues et al., 2011; Salmi et al., 2012). Moreover, some researchers compare PV cell single diode model with two diode model (Bhuvaneswari and Annamalai, 2011). According to results, single diode model is simpler and has acceptable accuracy. Furthermore, different simulation programs and ways have been used to analyze the PV cell model in the literature. Example simulation platforms are MATLAB/Simulink (Mohammed, 2011; Pandiarajan and Muthu, 2011; Tsai et al., 2008; Dang et al., 2012; Rodrigues et al., 2011; Salmi et al., 2012; Bhuvaneswari and Annamalai, 2011; Rekioua and Matagne, 2012), PSIM (Chao et al., 2008), SABER (Gow and Manning, 1999), and Maple software (Jain et al., 2006). All researches have been done with ready blocks of the programs.

MATLAB has ELEC_SOLAR.m file to model the solar cell operation. In the MATLAB model, series and shunt resistances are defined as input but this paper calculates resistances according to datasheet values. MATLAB model simulates for constant temperatures during simulation. On the other hand, the solar cell model can be simulated with the proposed model under variable temperature condition. These differences make superior proposed model in this paper than MATLAB model.

This paper focuses on analyzing single diode model of the PV panel with all system parameters, determining unknown model parameters based on the data taken from the datasheets, and obtaining the parameters of I–V and P–V characteristic curves. The comparison between the simulation results and the curves which are extracted from the datasheets according to experimental values is also presented. In particular, MATLAB S-function feature is used for simulation. The purpose of using S-function is creating generalized model, describing the model as a set of mathematical equations instead of ready blocks or functions, and incorporating any other systems. The main improvement of this paper, obtaining exact and general model of PV panels with only using mathematical equations and analyzing the presented model in discrete mode. Hence, this model can be used directly in embedded system applications and following systems (e.g. maximum power point tracking algorithm of boost converter) can operate according to model results.

2. Photovoltaic cell operation

A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells

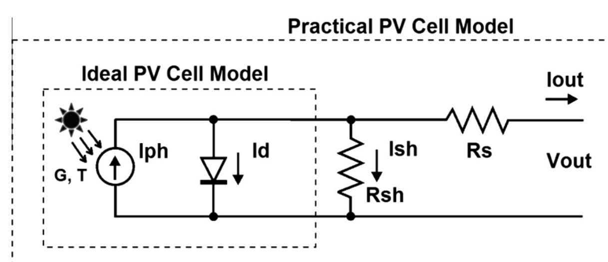

Fig. 1. Equivalent circuit of photovoltaic cell.

Table 1
Ideality constant for PV technology (Mohammed, 2011).

Technology	Ideality factor
Si-mono	1.2
Si-poly	1.3
a-Si:H	1.8
a-Si:H tandem	3.3
a-Si:H triple	5
CdTe	1.5
CIS	1.5
AsGa	1.3